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Environmental Support Requirements

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ABSTRACT

Apollo spacecraft atmosphere related data and implications are presented to assist the evaluation or performance of cabin atmosphere studies. Related studies being performed include the subjects of crew physiological constraints, cabin atmosphere enrichment, alternate oxygen systems and cabin atmosphere selection. The reference data contained in this report were selected and organized by reviewing the lunar mission phases and examining each significant mission phase for atmosphere related functions. Specific data are included on:

1. Mission phases and crew functions;
2. Environmental support requirements imposed on the Apollo system;
3. Mission timeline constraints;
4. Atmosphere pressure constraints.

The environmental support requirements for crew physiological needs of respiration and pressure are presented in general terms for the Apollo system. These requirements logically include providing a safe gaseous environment throughout the mission, providing alternate life support functions so a single failure is not fatal, enabling necessary crew tasks to be performed, etc. These overall spacecraft requirements are further interpreted to give more specific CSM and LM requirements. Significant design constraints considered appropriate for application to any environmental control system modifications undertaken are presented, e.g., minimizing existing system impact consistent with crew safety, continuing use of oxygen in the suit loop, continuing use of 5 psia oxygen as cabin flight pressurant and selecting launch cabin atmosphere based on achieving maximum overall mission crew safety.

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ABSTRACT (contd.)

Timeline constraints applicable to functions of modifying the environment after launch are derived based on current crew task definition and translunar injection opportunity plans. Time constraints are emphasized because of the potential effect on environmental control alternatives, e.g., dumping and repressurizing the cabin or purging the cabin at flight pressure. The time available for system operation or performance of crew tasks is very limited, particularly if any environmental control changes impose new functions to be accomplished before translunar injection. The translunar injection may occur as early as sometime between 50 and 140 minutes after launch based on trajectory considerations, providing crew tasks and equipment operations can be completed in time. Current predictions of the crew task timeline indicate a need to shorten rather than expand crew tasks in the early mission phases, before translunar injection, since planned tasks may take as much as 135 minutes. The implications are that any new provision for atmosphere control must not further burden the crew by adding serial tasks or interfering with existing tasks. Therefore, automatic operations (e.g., programmed oxygen enrichment or sensor initiated purging) are more attractive than those requiring manual tasks (e.g., dumping and repressurizing the cabin or removing helmets to use cabin atmosphere or oxygen masks as a backup).

System operating pressures are discussed with specific attention to the early launch phase when greatest pressure changes occur. The low pressures reached in flight, either nominal or abort, present a significant obstacle to the use of less than pure oxyten as a pressurant. In the first 155 seconds of a nominal launch the suit and cabin pressures drop from atmospheric to about 6 psia and sometime later reach 5 ± 0.2 psia. If an abort is initiated as early as or after 90 seconds, the cabin and suit pressures also decrease to about 6 psia.

In conclusion, it appears feasible to use an atmosphere other than oxygen for a cabin pressurant on the pad. However, environmental control system changes are required to achieve a safe system if a low oxygen content gas, e.g., air, is used as a cabin pressurant at launch. Candidate changes include changing cabin atmosphere before significant pressure decrease occurs (at lift-off or before T+155 seconds), adding an alternate oxygen system and selecting a gas with higher oxygen content than in air for on pad pressurant.

[redacted]

BELLCOMM, INC.

SUBJECT: Functional Requirements and Timeline Constraints for Cabin Atmosphere Evaluation, Apollo Saturn V - Case 330

DATE: September 30, 1967

FROM: R. D. Raymond

TM-67-2031-2

TECHNICAL MEMORANDUM

INTRODUCTION

Several studies currently are addressing the subject of Apollo atmosphere selection.(1,2,3,4) The subjects of these studies include related factors, e.g., crew physiological constraints, cabin atmosphere enrichment, alternate oxygen systems and cabin atmosphere selection. In order to better evaluate these studies or to aid the completion of them, a general review and a compilation of pertinent Apollo engineering data and operational requirements were performed. Particular attention was given to reviewing the phases of the lunar mission to determine the gross functional requirements of the Apollo Environmental Control System (ECS) and time constraints on system operation necessary to be compatible with the overall mission timeline.

The data presented in this memorandum are deemed to be generally applicable to spacecraft cabin atmosphere selection, whether the selection is between oxygen and air or some other gas composition. Included are the mission phases and functions, environmental support requirements,timeline constraints, and atmosphere pressure variations.

A general discussion of the significant parameters and requirements follows in this report under Mission Functions, Environmental Support Requirements, Timeline Constraints and Atmosphere Pressure Constraints. Significant implications noted up to the time of this report are included. It is anticipated, however, that the basic data presented will help formulate more specific conclusions and design requirements as implementation studies become more specific. Appendix A, of this report contains the detailed data on mission functions, timeline and pressure.

MISSION FUNCTIONS

The mission functions examined are illustrated in Appendix A, Table 1, LOR Mission Functions. Each phase of the mission from countdown through recovery is summarized and the crew functions affected by life support methods are shown.[5]

For each principal mission phase, e.g., countdown, ascent, etc., the overall time duration and gross crew functions are noted because of the importance of this information in evaluating ECS requirements. The life support mode provided for each mission phase is shown in context with the time period of use and the possible backup mode, e.g., during countdown pressure suits are backed up by cabin atmosphere, open hatch or possibly by oxygen masks (planned to be available for other use).

The primary method of supplying the crew with the necessary life supporting pressure and oxygen is either a pressure suit or a viable cabin atmosphere. The choice between these methods is effected by the balance of necessary crew functions versus reliability. Where practical in the current configuration the pressure garments are worn to enhance crew safety. At all other times in the mission the suits or helmets are doffed and the cabin atmosphere provides primary life support.

In order to enhance reliability, a backup to the primary method is required during all mission phases. Under nominal conditions the cabin atmosphere is a backup to the pressure garment and vice versa, except during lunar EVA. During EVA the only pressure garment backup is an oxygen purge system, provided to enable safe return at low suit leakage rates.

ENVIRONMENTAL SUPPORT REQUIREMENTS

The Apollo system is required to provide atmosphere related support for the crew physiological functions of respiration and body pressure. Thermal control must also be inherent in the environmental control system; however, only the gas composition and pressure are emphasized here. The Apollo Program Specification, SE 500-001-1 Revision A, requirements for crew safety and design were reviewed for direction in the current study. As interpreted here, the fundamental system requirements include:

1. The Apollo spacecraft shall provide a gaseous environment that will safely support the crew requirements for respiration and for a pressure environment throughout Apollo missions from crew ingress in the prelaunch phase to crew egress at recovery.

2. The Apollo spacecraft shall provide alternate functions such that a single failure in the supply and/or the maintenance of this gaseous environment will not result in loss of the crew.

3. The system shall enable necessary astronaut activities to be performed including CSM and LM control operations, crew transfer, houskeeping and EVA.

These system requirements applied to the lower level breakdown of the CSM and LM would impose the following specific spacecraft requirements.

1. <u>CSM</u> - The CSM system is required to provide gaseous environment functions as follows:

   a. The CSM shall provide a gaseous environment that will safely support the crew physiological requirements for respiration and pressure throughout the CM mission, from crew ingress during countdown through crew egress after recovery.

   b. The CSM gaseous environment shall be compatible with crew operations in a pressurized suit during all phases of the mission and compatible with crew shirtsleeve operations during long coasting flight periods when doffing of pressure suits is practical.

   c. Backup functions shall be provided so that a single failure in the environmental system will not result in loss of the crew.

2. <u>LM</u> - The LM system is required to provide basic life support functions (similar to the CSM) including the following:

   a. The LM shall provide a gaseous environment that will safely support the crew physiological requirements for respiration and body pressure from crew transfer to LM through return to the CSM, except for planned specific depressurized periods during lunar EVA.

b. The LM environment shall be compatible with crew operations in a pressurized suit during all phases of the LM mission and compatible with crew open helmet operations during LM pressurized lunar surface periods.

c. Backup functions shall be provided, where practicable, so that a single failure in the environmental system will not result in loss of the crew.

In evaluating the existing Apollo system environmental control capability and planning modifications to improve the capability to meet the system requirements, it is advisable to consider the following design criteria.

1. <u>CSM</u> - The appropriate CSM environmental control system specific design criteria include:

   a. Minimize the impact of modification to the existing environmental system consistent with crew safety.

   b. The existing pressure suit functions and basic design shall be retained. The suit shall be capable of maintaining a pure oxygen atmosphere internally while donned at a pressure greater than the cabin pressure and not less than 3.5 psia. Means for maintaining and indicating positive suit pressure shall be provided.

   c. The design shall enable the crew to be in pressurized suits supplied with pure oxygen from ingress during countdown until after orbit insertion at a minimum and possibly until after the first mid-course correction.

   d. The CM cabin atmosphere shall be pure oxygen at approximately 5 psia in flight by the time of initial doffing of suits in order to support shirtsleeve operations and the system shall be capable of maintaining a level of 5 ± 0.2 psia.

   e. The system shall enable a CM cabin leak check during countdown to be performed by increasing cabin pressure above external ambient pressure.

f. The gas to be used for CM pressurization during countdown and launch shall be selected to achieve maximum crew safety considering the total mission.

g. When oxygen is used as the CM cabin pressurant during countdown and ascent to orbit, the system shall demonstrate a capability of achieving crew safety by adequate fire prevention, retardation and extinguishment, as well as rapid egress when applicable.

h. When air (or similar composite gas) is used as the CM cabin pressurant during countdown and ascent to orbit, the system shall demonstrate a capability of achieving crew safety with respect to fire hazards, as with oxygen, and additionally a capability of supporting crew physiological requirements of respiration and pressure in the event of a suit loop failure.

i. When air (or similar composite gas) is used as the CM cabin pressurant during countdown, the system shall be capable of exchanging the initial cabin atmosphere for pure oxygen as soon as practicable after reaching a safe flight pressure and prior to initial doffing of suits.

j. The capability for maintaining survivable levels of atmosphere in the event of micrometeroid puncture shall be retained continuously throughout the mission.

2. <u>LM</u> - The appropriate LM environmental control system specific design criteria include:

   a. Minimize changes to the current LM environmental system design.

   b. Supplement the LM environmental system, if required, by addition of suit-related equipment, e.g., oxygen mask or direct suit or helmet supply, as and if developed for CM use.

TIMELINE CONSTRAINTS

The time constraints imposed on any added ECS functions, e.g., modifying the cabin environment after liftoff, are (1) to be compatible with available crew operating time, and (2) to be completed within the allowable ground elapsed time (g.e.t.). In both cases the most stringent time constraints will exist for the established first translunar injection (TLI) opportunity since available task time is a function of the time of TLI whether the tasks are performed before or after TLI.

Which TLI opportunity is to be used as the first TLI opportunity is not yet established. However, it most likely will be either the first Pacific, the second Atlantic or the second Pacific TLI opportunity. Therefore, the complete range of g.e.t. to TLI imposed by these three possibilities was considered with respect to time constraints on cabin environment functions. The corresponding TLI time constraints in terms of g.e.t. are approximately 50 minutes, 95 minutes and 140 minutes for the earliest TLI in each of the three cases, as shown in Appendix A, Tables 1 and 2. Of course, if TLI occurs for a specific flight after the first opportunity, more time is available for performing system operations. However, this does not relax the nominal time constraints for operational planning.

The crew availability time constraint cannot yet be quantized because other crew timeline functions are not yet firm. However, two effects that must be considered and minimized are the time required by one or more of the crew to operate the environmental system and the time that the operation might delay other crew tasks by interference, e.g., depressurization. Previous estimates of crew task timelines indicate a time of about 120 to 135 minutes is needed to accomplish all tasks up to TLI.(1) Since this time is already longer than allowable for the first two (and possibly three) potential TLI opportunities, it is desirable to interleave any additional tasks required for environmental control at negligible time cost. Furthermore, in implementing design changes the limited time available may require automation of functions.

A gross evaluation of the effect of timeline constraints on ESC modification designs shows very little difference between the three TLI times discussed. It does, however, indicate that the operating time available is very limited in all three cases, as shown in Appendix A, Table 2. For example, the time to orbit insertion is in all cases about 11 minutes. The time to TLI is less than 135 minutes (50 or 95 minutes) for either the "first Pacific" or "second Atlantic" and is only 140 minutes for the "second Pacific" opportunity.

Therefore, very little available time exists for new tasks. The implications are that automation of new operations should be considered and manual tasks should be avoided or simplified. Automatic environmental control operations for new functions might include provisions, e.g., programmed oxygen enrichment of cabin air, sensor initiated cabin or suit purging, etc. Manual operations that perhaps should be avoided include depressurizing the cabin, removing helmets to use cabin atmosphere or oxygen masks as a backup, etc.

ATMOSPHERE PRESSURE CONSTRAINTS

If air (or similar low oxygen content gas) is used in the CM cabin during the launch phase, the cabin atmosphere becomes unsuitable to support the crew as a backup to the suit loop shortly after launch.[2,6] In a nominal launch this condition exists because the cabin pressure drops from sea level to about 6 psia (at about 155 seconds after liftoff) during ascent and eventually leaks down to the controlled pressure of 5 ± 0.2 psia after orbit insertion. Also, if an abort is initiated during ascent as early as about 90 seconds after launch a low pressure of about 6 psia will be reached and will continue for a time duration depending on the time of abort.

The CM pressure history is described in Appendix A, Figure 1, both for nominal ascent and for abort during ascent. As shown in the figure, the nominal CM cabin pressure drops to $6^{+0.2}_{-0.4}$ psia during ascent. After ascent the cabin pressure eventually leaks down to a controlled level of 5 ± 0.2 psia. Also shown in Figure 1 is the cabin pressure for an abort; the cabin pressure drops to about 6 psia where it stays until pressure build up due to ambient pressure increase during re-entry.

In the nominal case the CM cabin pressure remains low after ascent. Therefore, a change in atmosphere composition is needed in order to attain a viable atmosphere providing that the initial atmosphere composition is not viable at 5 or 6 psia. However, in the abort case the cabin pressure may drop to about 6 psia and then return to a higher value during re-entry. The need and method for changing cabin atmosphere composition for abort are related to the time that the cabin pressure remains low.

The time at low cabin pressure (6 psia) in event of an abort is described in Appendix A. Figure 2 in the appendix shows that the pressure can be down to 6 psia for as little as 2 minutes for early aborts and as long as 16 minutes for later aborts that return the CM to earth before orbit. This period is essentially the time from abort initiation until the CM reaches an ambient external pressure of about 7 psia (when air bleeds in) during re-entry. Aborts that include going to a contingency orbit extend the time at low pressure to perhaps several hours (until entry is initiated).

Atmosphere related operating pressure ranges for CM, LM and suit are listed for reference in Appendix A, Table 4. For the nominal inflight case these pressures are around 5 psia. Since all pressure levels for flight are based on using oxygen in flight, it is advisable from a minimum hardware change viewpoint to use oxygen from early in the mission to minimize the impact on system design.

Considering the pressure constraints discussed, enrichment of the cabin atmosphere may be required in order to satisfy the physiological requirements imposed when the cabin atmosphere is used as a backup.[2,3] It is also appropriate to consider other means of providing a backup to the suit loop, either in addition to a viable cabin atmosphere or in lieu of a viable cabin atmosphere. A separate study was performed to evaluate requirements for such alternate oxygen systems as an oxygen mask and direct separate oxygen connections to the suit or helmet.[4]

CONCLUSION

The evaluation of the choice of a cabin atmosphere must carefully consider the functional requirements for physiological support of the crew and the constraints imposed by the existing system and environment. Although there are several implementation difficulties, there is no obvious reason why an atmosphere other than pure oxygen is not feasible as the CM cabin pressurant at launch. However, to assure adequate crew safety careful attention must be given to potential dangers in mission phases where a lack of oxygen in the CM cabin could compromise the environmental backup to the suit loop.

The pressure levels at which the system operates cannot easily be significantly changed; therefore, the atmosphere gas composition must be compatible with life support at close to the existing pressures. At the existing flight pressure oxygen is required to support planned crew operations in the cabin. Consequently, any alternate gas used at launch will require a means of changeover or enrichment sometime in flight.

The exchange of cabin atmosphere to oxygen appears to be warranted as early in the mission as practicable since the cabin atmosphere (if air) becomes nonviable shortly after lift-off. In addition, the cabin must be compatible with shirtsleeve operations within a few hours after launch to enable eating meals and initiating sleep cycles, as well as routine control and check operations.

In addition to providing backup of the pressure suit by the cabin (or backup of the cabin by the suit), it is appropriate to investigate the possibility that an added margin of safety and flexibility can be gained by providing an alternate oxygen system, e.g., a mask and oxygen tanks or separate oxygen supply to the suit.

R D Raymond

2031-RDR-jcd R. D. Raymond

Attachments
Appendix A

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APPENDIX A

ENVIRONMENTAL AND OPERATIONAL DATA SUPPORTING FUNCTIONAL REQUIREMENTS AND CONSTRAINTS

The detailed data collected or derived for this study are shown on the enclosed tables and figures as discussed below.

1. Mission Functions - The lunar mission functions examined are illustrated in Table 1. Each phase of the mission from countdown through recovery is included and the crew functions affected by the life support methods are stated. The configuration of the ECS life support mode (primary and backup) is summarized.

2. Timeline Constraints - The effects of time constraints in early phases of a mission on the selection of initial cabin atmosphere as related to subsequent (after launch) environment modification are shown in Table 2. In addition, reference to Table 1 gives an indication of the overall mission time constraints by significant phases, as well as gross functions of the crew at these times.

3. Atmosphere Pressure Constraints (Nominal) - During nominal ascent the CM cabin pressure remains at the initial value (sea level) until the external ambient pressure drops 6 psi below sea level (to approximately 9 psia). From this point the CM pressure tracks the ambient with a positive differential of $6^{+0.2}_{-0.4}$ psi. The CM cabin pressure relief valve closes when the ambient pressure is approximately 0, trapping approximately 6 psia in the cabin. From this time the CM pressure gradually decays due to leakage until, after several hours, the cabin regulators bleed in oxygen to maintain 5 ± 0.2 psia. Figure 1 illustrates the ascent conditions based on AS-501 and AS-504 reference trajectories.[5,7] The CM cabin pressure drops from sea level pressure to $6^{+0.2}_{-0.4}$ psia about 155 seconds after launch and nominally stays at or above 5 ± 0.2 psia throughout the rest of the flight.

4. <u>Atmosphere Pressure Constraints (Abort)</u> - In abort the CM pressure will either stay above $6^{+0.2}_{-0.4}$ psia or will drop to and remain at about 6 psia, depending on the time of abort. A gross approximation of the CM pressure for an abort at 90 seconds after launch is shown in Figure 1. The CM pressure drops to about 6.2 psia due to the altitude reached, because the external pressure at abort apogee is about 0.2 psia and the cabin pressure regulates to remain above ambient by about 6 psia during ascent. The CM cabin pressure will hold the value reached (6.2 psia) at abort apogee until the external ambient increases during entry to about 1 psi above cabin pressure. At this pressure differential the external air bleeds into the cabin causing the cabin atmospheric pressure to increase. This time of approximately 90 seconds after launch is a transition point for abort pressure since for earlier aborts the pressure does not drop this low and for later aborts the pressure remains at about $6^{+0.2}_{-0.4}$ psia until ambient pressure increases to a higher value on entry.

The type of re-entry abort, or modes, are defined as Modes I, II and III. Mode I (includes IA, IB and IC) uses the launch escape tower (LET) and ends at LET jettison (about 186 seconds). Mode IA includes abort from liftoff to about 30,000 feet at which time the sequence changes to retain the LET after abort until released by a barometric switch on the way down. Mode IB follows IA and ends above 100,000 feet, an altitude beyond which manual CM orientation control functions are required. Mode IC requires crew participation for manual CM orientation and rate damping and includes times from the end of Mode IB to LET jettison. Modes II and III aborts are with the SM attached after LET jettison and are differentiated by varying lengths of SPS thrusting to achieve the desired impact point.

For early aborts the CM cabin pressure remains above 6 psia because of the low abort apogees. However, as shown in Figure 1, beginning at about 90 seconds, in Mode I, the external ambient pressure allows CM cabin pressure decay to $6^{+0.2}_{-0.4}$ psia and prevents any increase until external ambient pressure has returned to about 7 psia (the cabin pressure relief valve vents in with a 1 psi differential). This occurs a few seconds after the time of chute deployment.

Appendix A (contd.)

The approximate time that CM pressure remains at its low value in an abort is shown in Figure 2 as a function of the time and type of abort. Also shown, for reference, is the time of low acceleration or free fall available between abort and entry, when manual crew actions would be possible. The time at low pressure is of interest because with low oxygen content atmospheres a problem exists in abort.[2] The time of low acceleration is of interest because it is indicative of the potentially available time for performing tasks necessary to provide a viable backup atmosphere. The data for plotting Figure 2 are shown in Table 3.[7] In this Table the ground elapsed time (G.E.T.) to 23,100 feet (or point of drogue deployment) was taken as the approximate time of CM cabin pressure increase since the additional time delay to actual start of pressure bleed in is quite short. The time of CM cabin pressure at $6^{+0.2}_{-0.4}$ psia was taken as the difference between time of abort and time of chute deployment, which corresponds essentially to the time when cabin pressure will increase during entry. The time at low acceleration was determined by the difference between the abort time and the G.E.T. to entry shown in Table 3.

For Mode I aborts between about 90 and 185.95 seconds (LET jettison) the time that CM pressure is at 6 psia is between 2 and 6 minutes. From LET jettison until about 400 seconds the CM cabin pressure is low for about 6.5 to 8 minutes during no-SPS-burn aborts (when time of free fall is too short for proper SPS burn). After 400 seconds Mode II/III aborts (with SPS burn) indicate times of 8 to 16 minutes for low CM pressure. After about 600 seconds abort to a contingency orbit results in extended periods of low CM pressure, similar to achieving nominal orbit.

5. Operating Pressure Levels (Suit and Cabins) - The range of atmosphere pressure values for both CM and LM and for the pressure garment assemblies are given for reference in Table 4. Unless major changes are made to the environmental control systems most of these pressure levels will have to be retained in the system design. Since the pressure levels are based on using pure oxygen, it is advisable to achieve an oxygen environment in the cabin as early in the mission as safety dictates in order to minimize the impact on system design.

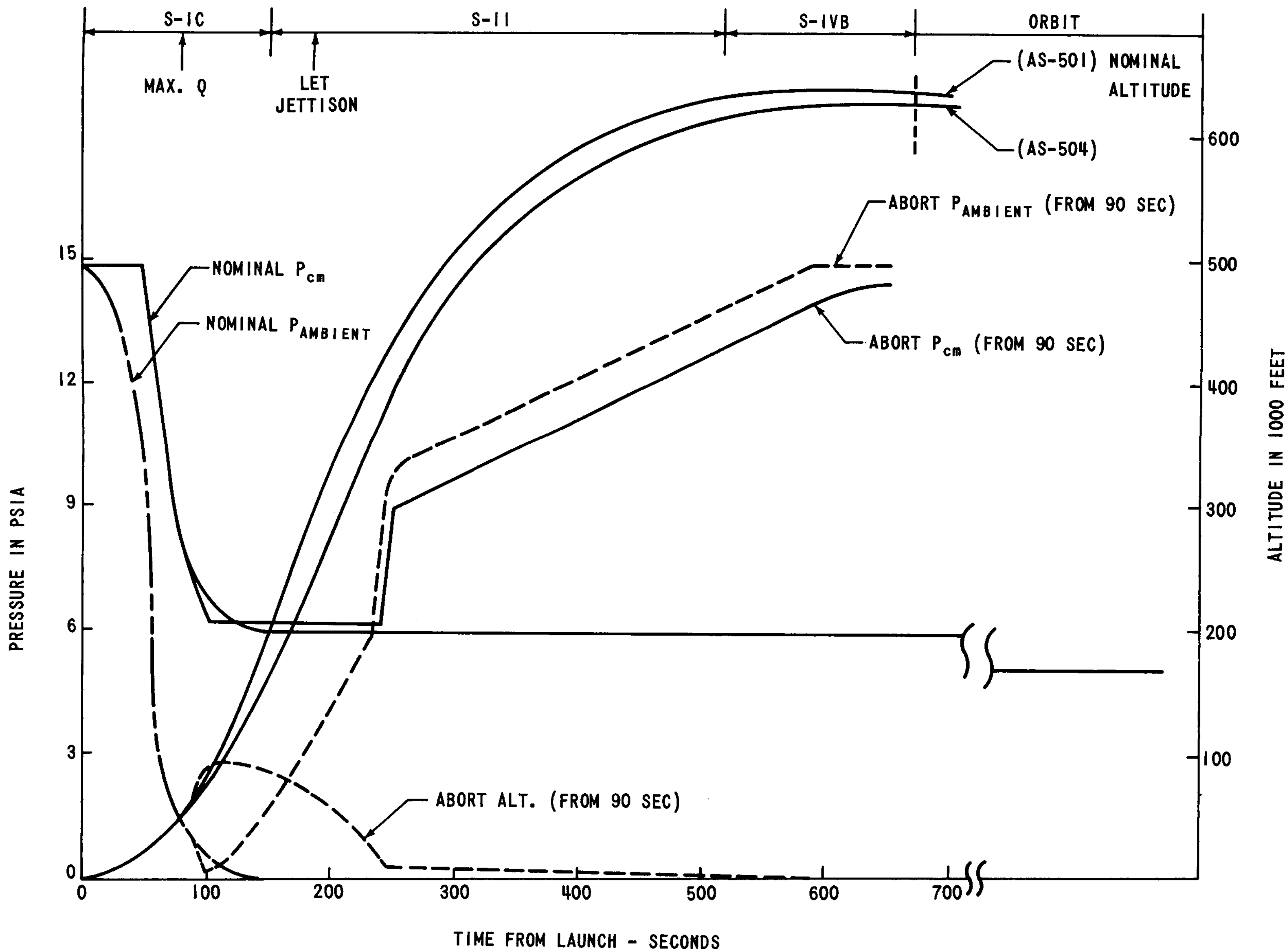

FIGURE 1 - NOMINAL PRESSURE vs. TIME FOR NOMINAL TRAJECTORY AND ABORT PRESSURE vs. TIME FOR EARLIEST ABORT THAT DROPS P_{cm} TO ~ 6 PSIA

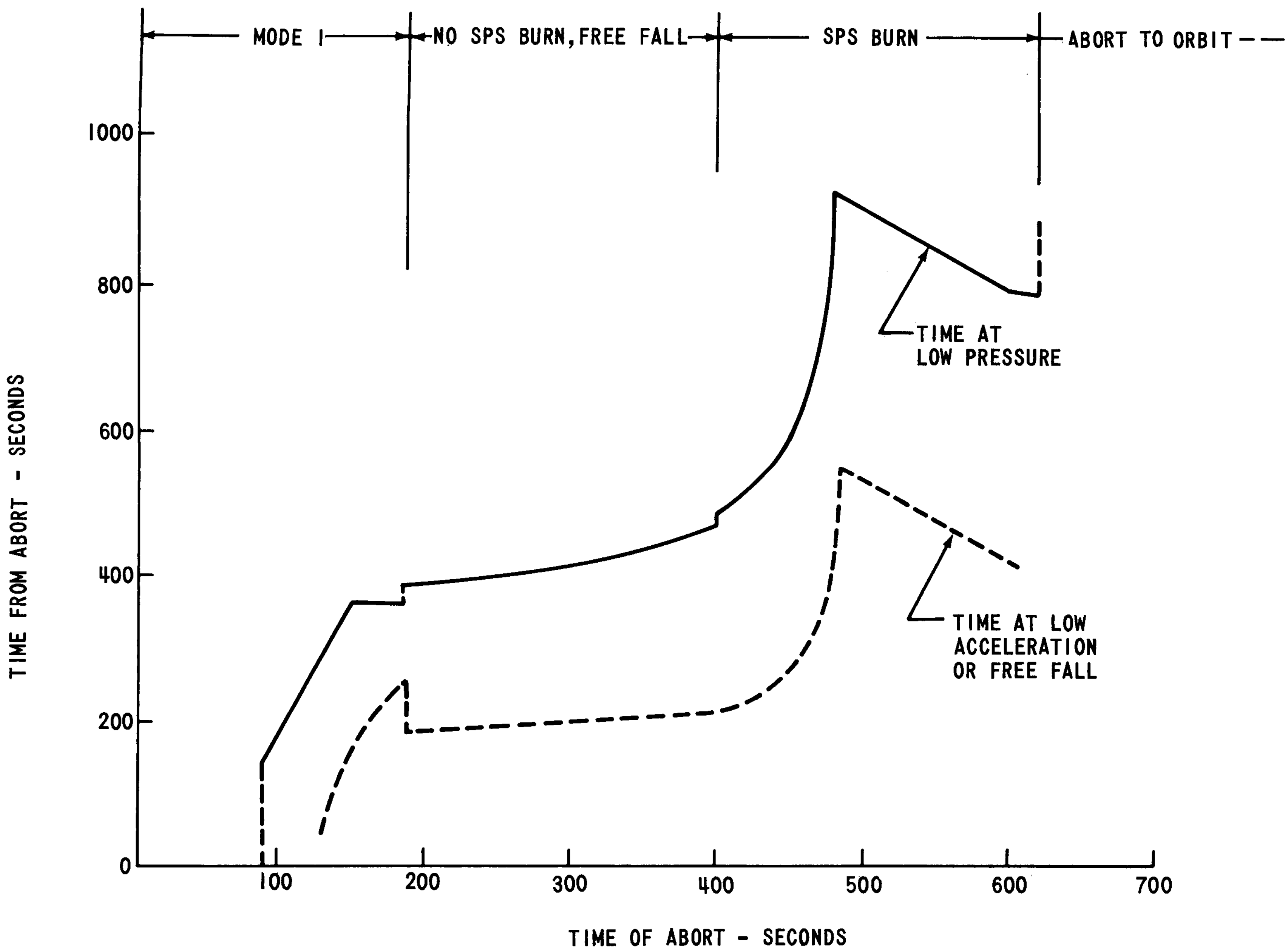

FIGURE 2 - TIME CM PRESSURE AT LOW VALUE (6 PSIA) AS FUNCTION OF TIME OF ABORT (BASED ON 501 ABORT PLAN)

MISSION PHASE	COUNTDOWN	ASCENT	EARTH ORBITING
Time Duration	Crew Onboard 1.5 Hours	11 Min.	50, 95 or 140 Min. to first TLI Opportunity
Crew Functions	1. Enter CM 2. Perform checks 3. Egress if abort on pad 4. L.E.T. abort; in couch to land, egress	1. Perform checks from couch 2. L.E.T., SPS or no SPS abort; in couch to land, egress	1. Perform checks from couch 2. Perform checks in L.E.B. 3. Deorbit for abort, in couch to land, egress
Primary Life Support Mode	Pressure suit	Pressure suit	Pressure suit
Backup Life Support Mode	1. Cabin atmosphere 2. Open hatch to ambient air 3. (Oxygen mask)	1. Cabin atmosphere 2. (Oxygen mask) and cabin pressure	1. Cabin atmosphere 2. (Oxygen mask) and cabin pressure

TABLE - 1 - 1

TLI THRU S-IVB JETTISON	TRANSLUNAR COAST THRU THIRD MIDCO CORRECTION	THIRD MIDCO CORRECTION THRU LOI	LOI THRU TRANSFER TO LM
65 Min.	61 Hours	1 Hour	3 Hours
1. Perform checks & control from couch 2. Perform dock operations in CM tunnel 3. For abort alter trajectory, continue operations, in couch before re-entry, land & egress	1. Perform checks & controls, including SPS burns, from couch 2. Eat & sleep cycle 3. Perform checks & operations in CM out of couch 4. Doff & don suits 5. For abort alter trajectory if req., continue operations, in couch before re-entry, land & egress	1. Perform checks & controls from couch 2. Perform checks from L.E.B. 3. If LM pre-LOI check made, trans. 1 man to LM & back to CM 4. For abort alter trajectory if req., continue operations, in couch for burns & entry, land & egress	1. Perform checks & controls from couch 2. Perform checks from L.E.B. 3. Control LM pressure, clear tunnel, transfer two crew to LM 4. Transfer equip. to LM 5. Initiate Lm systems 6. For abort enter CM, transearth injection, continue operations in couch for burns & entry, land & egress
Pressure suit	CM cabin atmosphere except during SPS burn operation when pressure suits are donned	Pressure suit	Pressure suit
1. Cabin atmosphere 2. (Oxygen mask) and cabin pressure	1. Pressure suit (cabin backup) 2. (Oxygen mask) (cabin backup) 3. Cabin atmosphere (press. suit backup) 4. (Oxygen mask) and cabin press. (suit backup)	1. Cabin atmosphere 2. (Oxygen mask) and cabin press.	1. Cabin atmosphere 2. (Oxygen mask) and cabin press. in CM 3. Cabin atmosphere in LM 4. (Oxygen mask) and cabin press. in LM

Table 1-2

TABLE I
LOR MISSION FUNCTIONS - ATMOSPHERE RELATED

CREW TRANS THRU LM SEPARATION	CSM SOLO OPERATION LM DESCENT	LUNAR SURFACE STAY
3 Hours	(LM) 1.5 Hours (CSM) 40 Hours	To 35 Hours
1. Perform CM operation from couch 2. Check LM from crew station 3. Secure tunnel & CM & LM hatches 4. Undock & separate with LM RCS 5. For abort enter CM and continue functions as in previous phases	1. Perform LM control from crew station 2. LM abort, return to CM 3. Perform CM functions of control & checks from couch & equip. bay (1 man) 4. CM crewman perform sleep & eat cycle	1. Perform checks from crew station 2. Prepare for EVA 3. Depress. LM 4. Egress 5. Perform lunar surface EVA 6. Enter LM & repressurize 7. Perform eat & sleep cycle 8. Repeat egress, EVA & ingress cycles 9. For abort enter LM, repress, check, launch
Pressure suit (CM) Pressure suit (LM)	Pressure suit (LM) Pressure suit part time (CM), Cabin atmosphere part time (CM)	Pressure suit part time LM atmosphere part time (Suit/PLSS during ingress/egress & EVA)
1. Cabin atmosphere (CM) 2. (Oxygen mask) and cabin press. (CM) 3. Cabin atmosphere (LM) 4. Common LM/CM atmosphere during transfer	1. Cabin atmosphere (LM) 2. Cabin atmosphere (CM) suit backup 3. Press. suit (CM) (cabin backup) 4. (Oxygen mask) & cabin press. (CM) (suit backup) 5. (Oxygen mask)(CM) (cabin backup)	1. Cabin atmosphere (suit backup) 2. Press. suit (cabin backup) 3. Backup for press. suit/PLSS limited to ECS umbilical supply in LM, or oxygen purge system (OPS) during EVA.

TABLE I-3

LM ASCENT AND RENDEZVOUS	DOCKING AND CREW TRANS.	CREW TRANS. THRU TEI.
2.5 Hours	1 Hour	3 Hours
1. Perform checks & control from crew station 2. For abort continue operations from crew station using AGS or waiting CM rescue	1. Perform checks & control from crew station in LM 2. Perform checks & control from couch in CM 3. Perform manual docking tasks in tunnel of CM 4. Perform manual docking tasks in tunnel of LM 5. Transfer crew & equip. to CM 6. Secure tunnel hatches from CM 7. For abort enter CM & proceed to TEI 8. For docking backup perform EVA, depress. LM & CM, transfer LM crew with OPS (two)	1. Perform tasks from CM couch & equip. bay 2. Secure crew in couch for TEI 3. For abort proceed thru TEI
Pressure suit	Pressure suit (LM) Pressure suit (CM)	Pressure suit
1. Cabin atmosphere	1. Cabin atmosphere (LM) 2. Cabin atmosphere (CM) 3. Cabin press. & (oxygen mask) (CM) 4. Common LM/CM cabin atmosphere during transfer	1. Cabin atmosphere 2. (Oxygen mask) and cabin pressure

TABLE 1-4

TRANSEARTH COAST THRU FINAL MIDCO CORRECTION	FINAL MIDCO CORRECTION THRU SM JETTISON	ENTRY & LANDING	RECOVERY
87 Hours	1 Hour	20 Min	
1. Perform checks & controls from couch 2. Perform checks from equip. bay 3. Eat & sleep cycle 4. Doff & don suits 5. For abort continue operations, in couch before entry, land & egress	1. Perform tasks from couch	1. Perform tasks from couch	1. Prepare for egress
CM cabin atmosphere except during SPS burn operations when press. suits are donned	Pressure suit	Pressure suit	Pressure suit Cabin atmosphere
1. Press. suit (cabin backup) 2. (Oxygen mask) (cabin backup) 3. Cabin atmosphere (press. suit back) 4. (Oxygen mask) & cabin press. (suit backup)	1. Cabin atmosphere 2. Cabin press. and (oxygen mask)	1. Cabin atmosphere 2. Cabin pressure and (oxygen mask)	1. Cabin atmosphere 2. (Oxygen mask) 3. Open hatch to ambient air

NOTE: (Oxygen mask) indicates anticipated new equipment when and if added.

Table 1-5

TABLE 2

TIME CONSTRAINT EFFECTS

TLI OPPORTUNITY	APPROXIMATE AVAILABLE GROUND ELAPSED TIME (G.E.T.) (MINUTES)	APPROXIMATE AVAILABLE "CREW TASK TIME" (MINUTES)	POTENTIAL ENVIRONMENTAL CONTROL FUNCTIONS	TIME APPRAISAL; ADEQUATE (A) QUESTIONABLE (Q)
FIRST PACIFIC EARLIEST TLI ≈50 MIN G.E.T.	11 MIN TO ORBIT; 50 MIN TO TLI; 115 MIN TO S-IVB JET; 240 MIN TO FIRST MIDCOURSE CORRECTION (M.C.)	≈0 MIN TO ORBIT; ≈0 MIN TO TLI; SOME POSSIBLE TO S-IVB JET; SEVERAL MIN TO FIRST M.C. (ASSUMES THAT EXISTING TASKS REQUIRE MORE THAN THE 50 MIN TO TLI)	1. DEPRESS TO ZERO & REPRESS BY TLI 2. ENRICH BY ORBIT INSERTION (CONTINUOUS) 3. ENRICH BY TLI (CONTINUOUS) 4. ENRICH BY S-IVB JET (CONTINUOUS) 5. ENRICH BY FIRST M.C. (CONTINUOUS) 6. DEPRESS/REPRESS INCREMENTALLY BY TLI 7. DEPRESS/REPRESS INCREMENTALLY BY S-IVB JET 8. DEPRESS/REPRESS INCREMENTALLY BY FIRST M.C.	1. Q 2. Q 3. Q 4. Q 5. A 6. Q 7. A 8. A
SECOND ATLANTIC, EARLIEST TLI ≈95 MIN G.E.T.	11 MIN TO ORBIT; 95 MIN TO TLI; 160 MIN TO S-IVB JET; 285 MIN TO FIRST M.C.	≈0 MIN TO ORBIT; ≈0 MIN TO TLI; SOME POSSIBLE TO S-IVB JET; SEVERAL MIN TO FIRST M.C. (ASSUMES THAT EXISTING TASKS REQUIRE MORE THAN THE 95 MIN TO TLI)	1. 2. 3. 4. 5. (SAME AS ABOVE) 6. 7. 8.	1. Q 2. Q 3. Q 4. Q 5. A 6. Q 7. A 8. A
SECOND PACIFIC, EARLIEST TLI ≈140 MIN G.E.T.	11 MIN TO ORBIT; 140 MIN TO TLI; 205 MIN TO S-IVB JET; 330 MIN TO FIRST M.C.	≈0 MIN TO ORBIT; SEVERAL MIN TO TLI; SOME POSSIBLE TO S-IVB JET; SEVERAL MIN TO FIRST M.C. (ASSUMES THAT EXISTING TASKS REQUIRE LESS THAN 140 MIN TO TLI)	1. 2. 3. 4. 5. (SAME AS ABOVE) 6. 7. 8.	1. Q* 2. Q 3. Q* 4. Q 5. A 6. Q* 7. A 8. A

*SLIGHTLY MORE USABLE TIME AVAILABLE THAN FIRST TWO TLI POSSIBILITIES LISTED.

TABLE 3

GROUND ELAPSED TIME (G.E.T.) FOR VARIOUS ABORT MODES

ABORT MODE	TIME OF ABORT (MIN:SEC)	ABORT ALTITUDE (FEET)	ABORT APOGEE ALTITUDE (FT)	G.E.T. TO ENTRY (MIN:SEC)	G.E.T. TO 23,100 FT (MIN:SEC)
MODE I	1:30	57,556	93,799	--	3:54
	1:50	93,117	192,123	--	5:38
	2:10	138,597	299,973	--	6:59
	2:30	195,388	448,383	--	8:33
	2:50	254,076	464,626	--	8:48
	3:05.95	296,001	483,760	7:10	9:03
NO SPS BURN	3:05.95	*	*	6:15	9:36
	4:00			7:15	10:39
	5:00			8:18	11:56
	6:00			9:22	13:25
	7:00			10:38	15:23
MODE II/III	6:40	*	*	10:13	14:42
	7:00			10:48	15:37
	8:00			16:56	23:27
	9:00			16:50	23:20
	10:00			16:50	23:12

*NOTE: ALTITUDE IN ALL CASES IS HIGHER THAN REQUIRED TO BRING CM PRESSURE TO 6 PSIA.

TABLE 4

NOMINAL OPERATING PRESSURE RANGES

MISSION PHASE	CM CABIN ATMOSPHERE (PSIA)	PRESSURE SUIT (PSIA)	LM CABIN ATMOSPHERE (PSIA)
COUNTDOWN	CABIN LEAK CHECK $\approx 14.7+$(TBD) OPERATING ≈ 14.7 AT LAUNCH ≈ 14.7	CABIN LEAK CHECK $\approx 14.7+$(TBD) OPERATING $\approx 14.7+.36$ AT LAUNCH $\approx 14.7+.36$	CABIN LEAK CHECK $\approx 14.7+$(TBD) AT LAUNCH ≈ 14.7
ASCENT	INITIAL ≈ 14.7 FINAL $6\pm^{.2}_{.4}$	INITIAL $\approx 14.7+.36$ FINAL $\approx 6\pm^{.2}_{.4}+.36$ (IF CM CABIN IS ZERO $3.75\pm.25$)	INITIAL ≈ 14.7 FINAL 5.4 TO 5.8
EARTH PARKING ORBIT	$6\pm^{.2}_{.4}$	$6\pm^{.2}_{.4}+.36$ (IF CM CABIN IS ZERO $3.75\pm.25$)	≈ 5.4 TO 5.8
TLI THROUGH S-IVB JETTISON	$6\pm^{.2}_{.4}$ TO $5\pm.2$	$(6\pm^{.2}_{.4}$ TO $5\pm.2)+.36$ (IF CM CABIN ZERO $3.75\pm.25$)	≈ 5.4 TO 5.8
TRANSLUNAR COAST THROUGH THIRD (M.C.)	INITIAL $6\pm^{.2}_{.4}$ TO $5\pm.2$ FINAL $5\pm.2$	INITIAL (SUIT DONNED) $(6\pm^{.2}_{.4}$ TO $5\pm.2)\pm^{.36}_{.13}$ FINAL (SUIT DONNED) $(5\pm.2)\pm^{.36}_{.13}$ (IF CM CABIN ZERO $3.75\pm.25$) SUIT DOFFED $5\pm.2$	INITIAL ≈ 5.4 TO 5.8 FINAL ≈ 0

TABLE 4 (CONTINUED)

THIRD M.C. THROUGH LOI	5±.2	(5±.2)+ ≈.1 (IF CM CABIN ZERO 3.75±.25)	0
LOI THROUGH TRANSFER TO LM	BEFORE HATCH OPEN 5±.2 DURING TRANSFER 5±.2	BEFORE HATCH OPEN (5±.2)+ ≈.1 DURING TRANSFER (5±.2) ≈.1 AFTER UMBILICAL TRANSFER 5+.1	BEFORE HATCH OPEN ≈5 DURING TRANSFER ≈5
CREW TRANSFER THROUGH LM SEPARATION	BEFORE HATCH CLOSED 5±.2 AFTER SEPARATION 5±.2	CM - BEFORE HATCH CLOSED (5±.2)+.1 LM - BEFORE HATCH CLOSED ≈5+ ≈.1 CM - AFTER SEP. (5±.2)+≈.1 LM - AFTER SEP. (4.8±.15)+≈.1	BEFORE HATCH CLOSED 5 AFTER SEPARATION 4.8±.15
CSM SOLO	5±.2	SUIT DONNED (5±.2)+ ≈.1 SUIT HELMET DOFFED 5±.2 (IF CM CABIN ZERO 3.75±.25)	N/A
LM DESCENT	N/A	(4.8±.15)+ ≈.1 (IF LM CABIN ZERO 3.8±.15)	4.8±.15
LUNAR SURFACE STAY	N/A	LM PRESSURIZED (4.8±.15)+ ≈ .1 LM UNPRESSURIZED 3.8±.15 WHEN PLSS USED (EVA) 3.8±.1	IN LM 4.8±.15 EVA 0
LM ASCENT & RENDEZVOUS	N/A	(4.8±.15)+ ≈.1 (IF LM CABIN ZERO 3.8±.15)	4.8±.15

TABLE 4 (CONTINUED)

DOCKING & CREW TRANSFER	BEFORE DOCK $5 \pm .2$ AFTER HATCH OPEN $5 \pm .2$ AFTER HATCH CLOSED $5 \pm .2$	CM - HATCH CLOSED $(5 \pm .2) + \approx .1$ CM - HATCH OPEN $(5 \pm .2) + \approx .1$ LM - HATCH CLOSED $(4.8 \pm .15) + \approx .1$ LM - HATCH OPEN $\approx 5 + \approx .1$	BEFORE DOCK $4.8 \pm .15$ AFTER HATCH OPEN ≈ 5 AFTER HATCH CLOSED ≈ 5
CREW TRANSFER THROUGH TRANSEARTH INJECTION	$5 \pm .2$	$(5 \pm .2) + \approx .1$ (IF CM CABIN ZERO $3.75 \pm .25$)	N/A
TRANSEARTH COAST THROUGH FINAL M.C. COR	$5 \pm .2$	SUIT DONNED $(5 \pm .2) + \approx .1$ SUIT DOFFED $5 \pm .2$ (IF CM CABIN ZERO $3.75 \pm .25$)	N/A
FINAL M.C. THROUGH SM JETTISON	$5 \pm .2$	$(5 \pm .2) + \approx .1$ (IF CM CABIN ZERO $3.75 \pm .25$)	N/A
ENTRY AND LANDING	INITIAL $5 \pm .2$ FINAL ≈ 14.7	INITIAL $(5 \pm .2) + \approx .1$ FINAL ≈ 14.7	N/A
RECOVERY	HATCH CLOSED ≈ 14.7 HATCH OPEN ≈ 14.7	SUIT DONNED ≈ 14.7 SUIT HELMET DOFFED ≈ 14.7	N/A